Science Behind Sails

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Sail Cloth

It is important to understand and identify the physical properties of sailcloth to be able to trim your sails to best advantage.

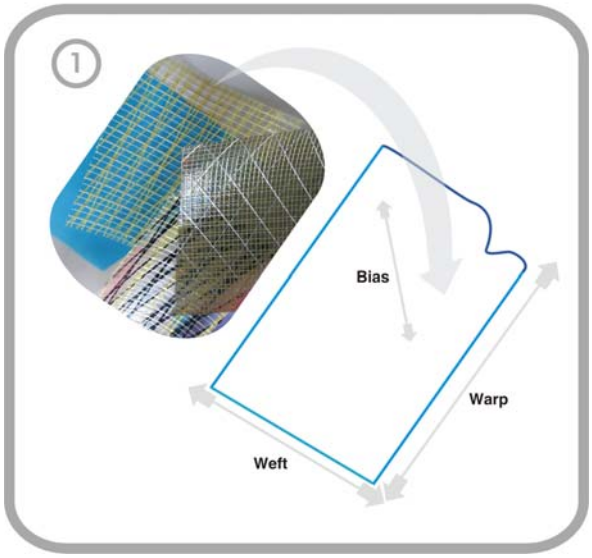
Polyester - generally known as Dacron. The chemical composition of the yarns is all the same except for the differences in size of yarn, the way they are woven and the finish that is applied.

The stability of the cloth depends on the tightness of the weave and the number of yarns to a unit area. In addition, the stability of the bias, or diagonal is greatly improved by the finishing process often in the form of a resin coating. Diagonal stability is often achieved at the expense of stability along the length and width. It is necessary for the sail maker to take all of these factors into account when choosing the cloth he needs - usually stability on the bias is a prime factor.

Mainsails are subject to heavy loads along the leech (or weft line of the cloth) whilst Genoa's receive the loads in line with the sheet (or along the bias of the cloth).

Laminated Cloths

Mylar is a trade name for a polyester film. It is the same as the polyester in normal cloth but extruded into a film rather than a fibre. Because it is a multi-directional film it effectively eliminates the weak bias of conventional cloth giving more stable characteristics. A woven scrim cloth is bonded to the Mylar film to aid the tear resistance and ease of handling. When Mylar was first introduced the adhesive was the weak link, often resulting in delamination. Over the seasons there has been considerable development of bonding techniques and now delamination is less frequent.



Kevlar on the other hand relies on the strength of the Kevlar fibres to control shape and so the covering film of Mylar can be much thinner. Cloth manufacturers can therefore align the fibres to the load lines on the sail and because of Kevlar's immense strength can reduce the overall weight of the sail, an important factor on larger yachts.

Choice of Cloths

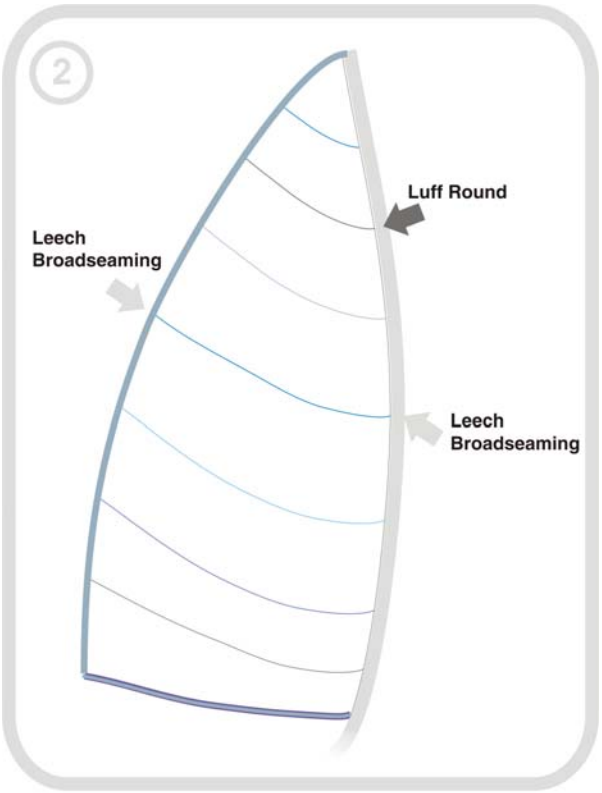
Pinnell & Bax are constantly testing and developing new sail cloths as they become available, to identify their characteristics - for control, stability, etc. Sails which need a large variation in setting to obtain the best all-round performance, for example the Contender, Solo, and Europe dinghies, would need to be made from stretchable impregnated materials, whereas sails which are subject to high loads and set on stiffer rigs, for example the 505, Fireball and Flying 15, would be made from a stable coated material.

Sail Shape

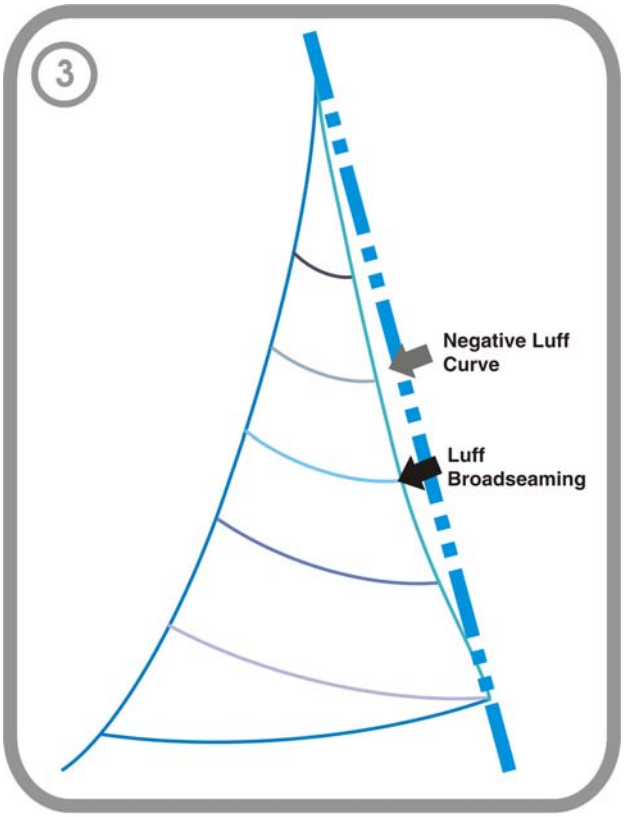
In order to create the desired amount of fullness the sail is designed and developed by shaping seams. Mast bend has to be taken into account as this will affect both the fullness and the degree of change between flat
and very full.

Shape is built into a mainsail using two methods (fig 2):-

1) Broadseaming is simply curving the edge of the cloth panel so that when joined to the straight edge in the next panel it forces camber into the sail. Broadseaming introduces an aerofoil l shape to the sail generally curved in the luff area (front) and straight in the leech (back).



2) Luff round. Further shaping is added to the sail by making a convex curve on the luff side of the sail. If the sail is set onto a straight mast this results in extra fullness forced back into the sail For this reason mast bend must match the luff curve of the sail. Too much luff round results in too much fullness in the sail entry, Too little luff round - a flat or distorted entry commonly known as luff starvation.



The foresail is built in the same way using smaller amounts of broadseaming and usually negative luff curve, as there tends to be luff sag (fig 3) Once again the rig must be tuned to fit the sail.

Mast & Spreaders

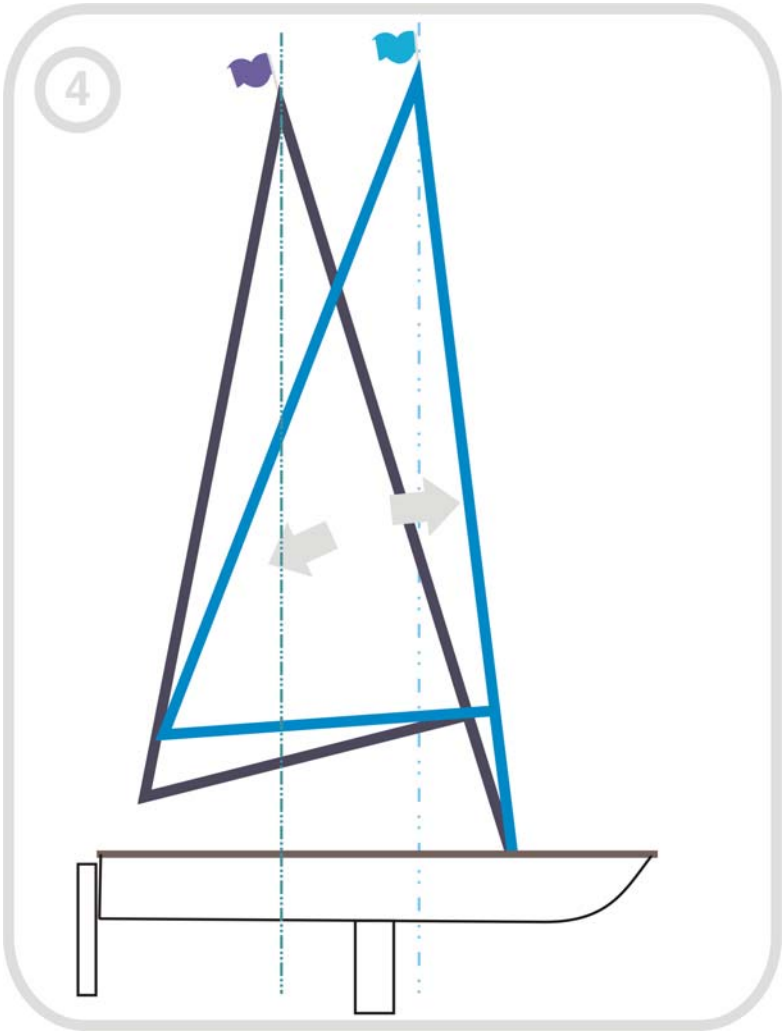
The first requirement for a good mast is that it supports the sails correctly, bending in just the right way to enable the sail to set efficiently to produce maximum drive in a variety of wind and sea conditions.
If you are selecting a new mast for your boat, look around the class and observe what the winning boats are using with similar crew weights. We, at Pinnell & Bax, are only too willing to offer advice on the right most for your class of boat.

Rake

It is generally accepted that boats go faster to windward with their mast raked aft and faster downwind with their masts raked forward. In light winds the mast is set in its most forward raked position and progressively raked further aft as the wind strength increases. Many boats are rigged to enable mast rake to be adjusted whilst sailing, by a combination of jib halyard and shroud adjustment. Raking has several side effects. As the mast is raked back the centre of effort moves aft and is lowered (Fig 4), Prebend is effected as the spreaders move aft increasing mast bend and flattening the sail. Raking the mast also alters the rake of the jib, opening the jib slot and depowering the rig.
Two points to remember are that

a) The mast must be a tight fit at the heel, as any movement here detracts from the effect of the spreaders, and

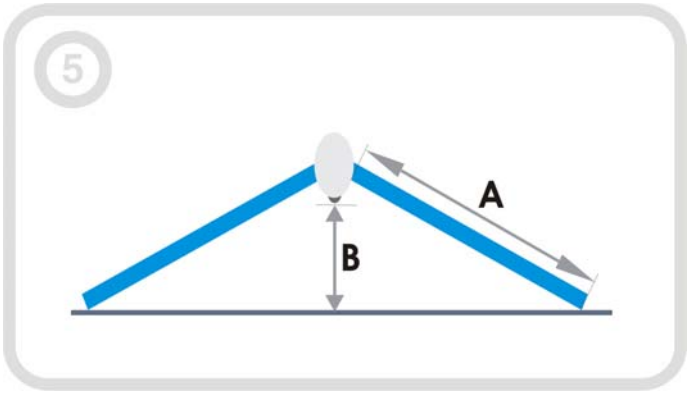
b) It must also be a tight fit at deck level to reduce sideways most bend as much as possible.



Spreaders

The spreaders are the major factor in control of mast bend. The combination of spreader length and deflection will determine the effect the spreaders have on the mast. By changing either or both settings it is possible to completely alter the bending characteristics of the most. Consequently proper spreader settings are extremely important for correct most bend and sail setting.

The length of the spreaders directly influences the sideways stiffness of the mast. The longer the spreaders are the stiffer the mast will behave sideways. Thus if the boat feels overpowered the spreaders should be shortened and vice versa.
Spreader deflection affects fore and aft most bend. A large angle of sweep back increases most bend, flattening the mainsail and opening the leech - more suitable for lighter crews. A small angle deflecting the shrouds forward stiffens and straightens the mast, suitable for heavy crews or where maximum power is required.
Average deflection for dinghies is 1" outwards and neutral forward and aft. On high performance trapeze classes average deflection is 2 1/2" outwards and 1" forward. The precise amount can only be assessed through experience and experiment,



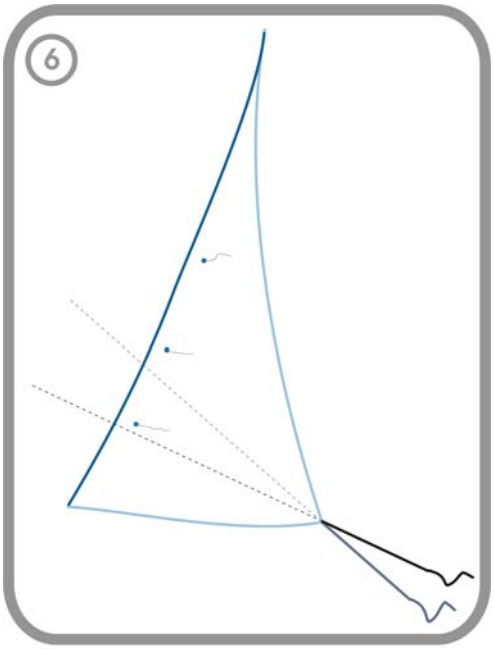
For the Pinnell & Bax tuning sheet for your particular class click:

http://www.pinbax.com/index.asp?selection=Tuning%20Guides

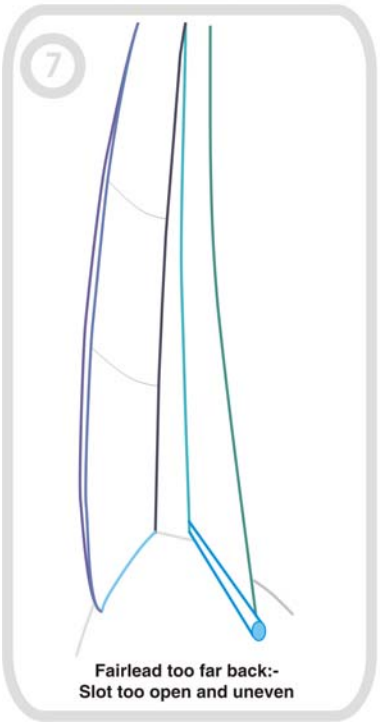
Rig Tension

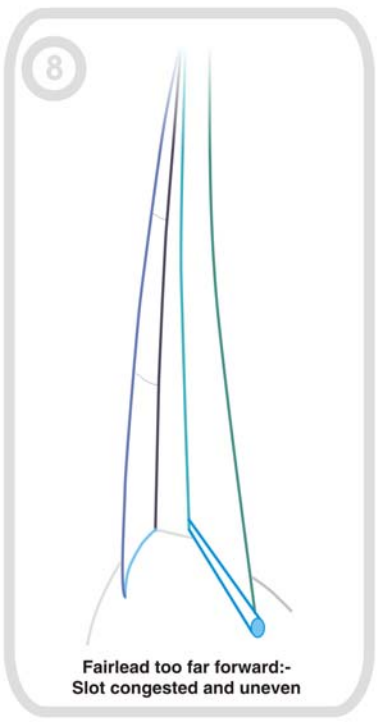
Rig tension can also contribute to mast stiffness. The more rig tension being used the less spreader length and deflection is required to keep the rig straight and vice versa. You can prebend the mast if a lot of rig tension is applied by having longer spreaders and a large deflection back. This will only be advantageous in ghosting conditions. You have to have a lot of faith in the conditions staying the same for this setting, otherwise the small advantage in very light airs could change to a great disadvantage in medium airs. Rig tension is also covered in other areas of the website.

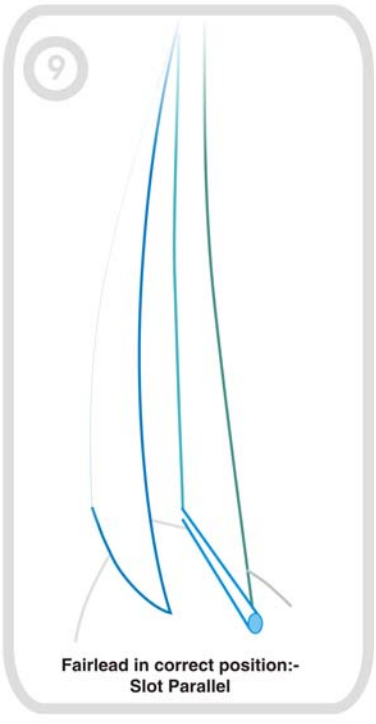
The Slot



The slot is one of the most important factors involved in producing upwind boat speed. To obtain the ideal slot the leech of the jib must match the profile of the main. If the mainsails leech is twisted open, then the jib leech should be set in unison.
There has been a trend towards closer jib sheeting in recent years. This can only work if both the main and jib are compatible, and the jib sheeting position, now nearer the centerline, is accurately controlled. Make sure that your sheeting system works well and can be calibrated.
The easiest way to determine fore and aft fairlead position for different wind strengths, is to act on the information received from the tell-tales. If the top tell-tale lifts before the lower, there is too little leech tension and the fairleads should be moved forward (Fig 6). Should the reverse apply, the lower tell-tale lifting before the upper, there is too much leech tension and the fairleads should go aft. Correct tension is indicated by tell-tales lifting simultaneously (Fig 7,8,9). It would be a good idea to record fairlead positions and sheet settings for different wind strengths so that they can be repeated. Jib sheets can be marked with a felt-tip pen and fairlead positions recorded using our self adhesive calibrated strips.
http://shop.pinbax.com/index.asp?selection=category&InBox=Calibration%20Strips&countstart=0



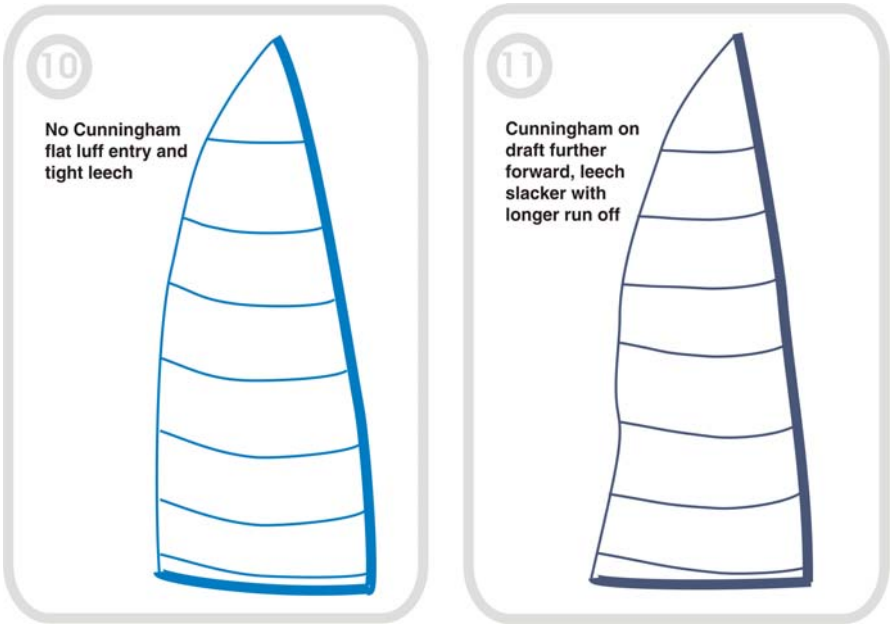




The Cunningham

This is a powerful adjustment to the sail shape and can make a considerable influence to boat speed, when used in conjunction with the jib and setting the slot. Care must be exercised because too much tension will pull the mainsail flow forward choking the slot. In recent seasons many 'fast' helmsmen sail to windward increasingly with no Cunningham tension to keep the slot 'soft'.

In stronger winds Cunningham tension can be used to assist the upper mainsail leech to open. By pulling firmly downwards the sailcloth is distorted, holding the flow forward in the sail and allowing the leech to open. This will have the effect of sailing with a flatter, more controllable sail in strong winds.

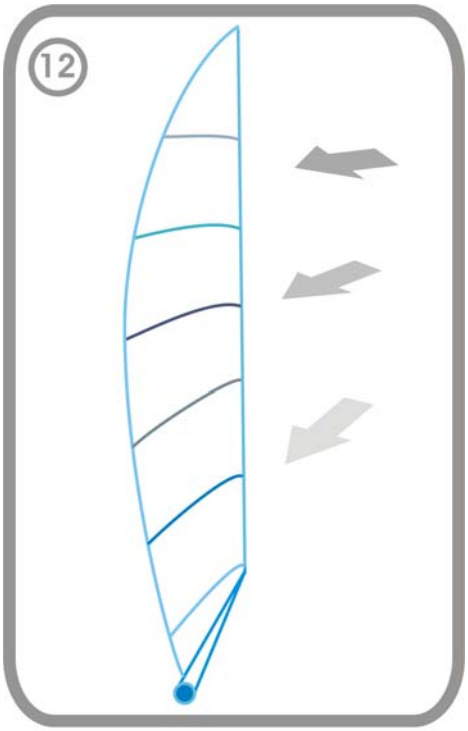


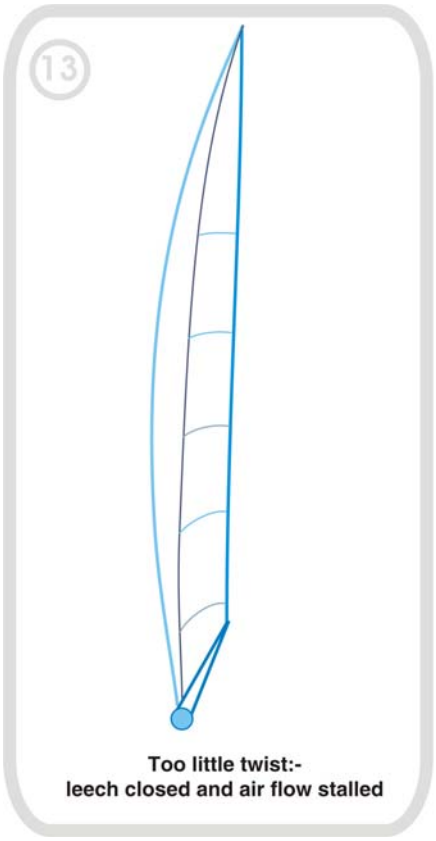
Sail Twist

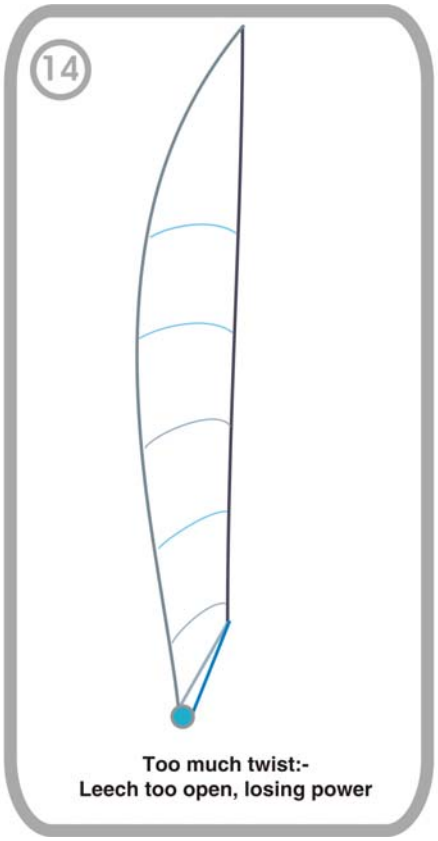
Due to friction over the water windspeed is less at the base of the sail than at the head. Consequently the head has to accept increased wind. The result is that the apparent wind at the head is further aft than the wind at the base. The need for sail twist is therefore evident.

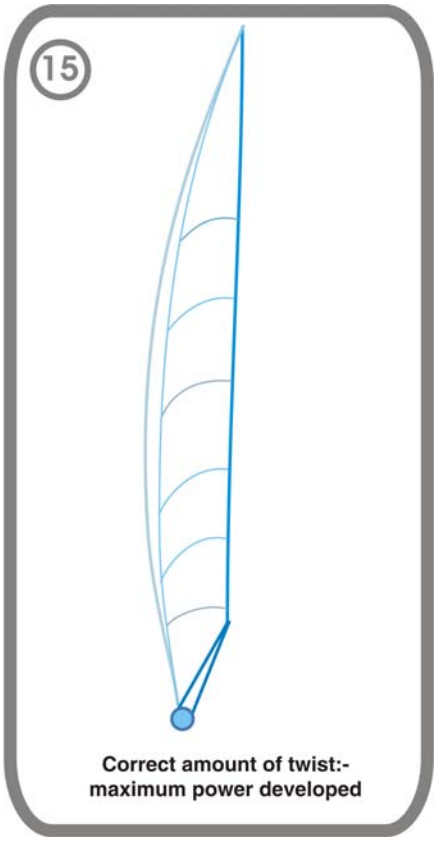
As mentioned previously, the slot between the main and jib should twist to the same degree. The amount of twist varies according to the conditons of the wind and water but roughly 10 degrees of twist is a good general value When designing our sails we incorporate the abillty to twist, both the mainsail and foresail.

Tell-tales are a useful guide to setting the correct amount of twist in both mainsail and jib.



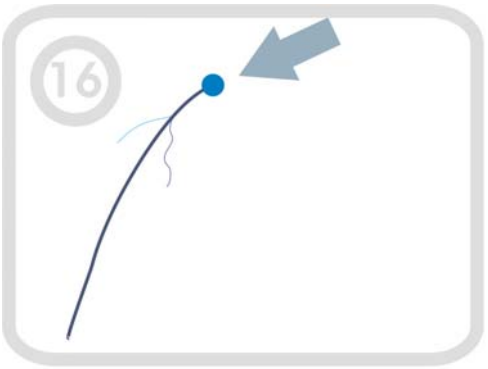






Tell Tales

With modern harder finishes and therefore less sensitive sail cloths, jib tell-tales are an essential guide in indicating whether the boat is being sailed too high or too low, or whether the jib is sheeted too hard or too slack. When a boat is being sailed correctly upwind, both the windward and leeward luff tell-tales will stream aft horizontally. 'Pinching' results in the windward luff tell-tales lifting upwards. If the leeward tell-tales lift, you will be sailing too low. Under certain conditions, e.g. the close proximity of other boats, overhanging projections such as trees, bridges, banks of rivers, etc. one should not rely wholly on the performance of tell-tales.
Tell-tales are also invaluable when sailing a reaching course. If the windward tell-tales lift, sheet in; if the leeward tell-tales lift, ease the sheet.



Leech tell-tales are also fitted to the mainsail normally at the batten pockets. Their purpose is to indicate the air flow over the leech area of the sail enabling the helm and crew to adjust mast bend, kicking strap, and main sheet tension for optimum pointing ability and maximum speed when beating. Ideally, when the main is set all leech tell-tales should be streaming aft, with the upper one tending to flick to leeward for 30-40 % of the time . This will vary depending on the class and conditions (fig 17).

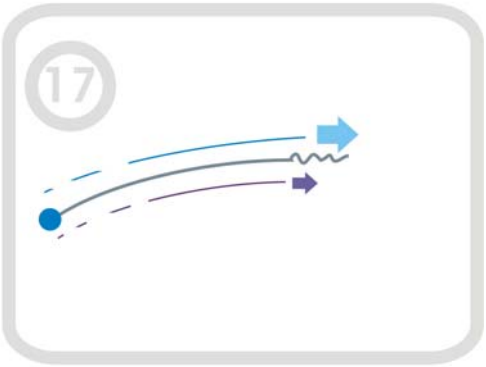
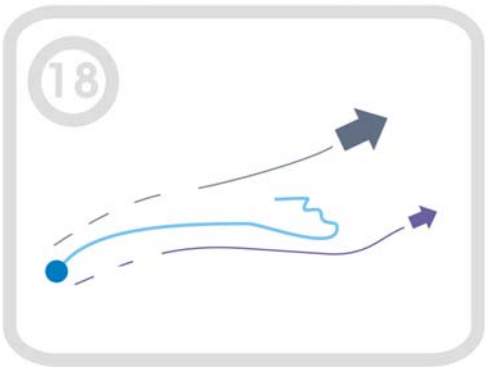


Fig 18 shows a mainsail over kickered and with too straight a mast viewed from above. The tell-tales are showing that the leech is stalled and that the air is flowing from the windward to the leeward side of the sail. In this instance you would be pointing well but going slow.



Sail Setting in light winds

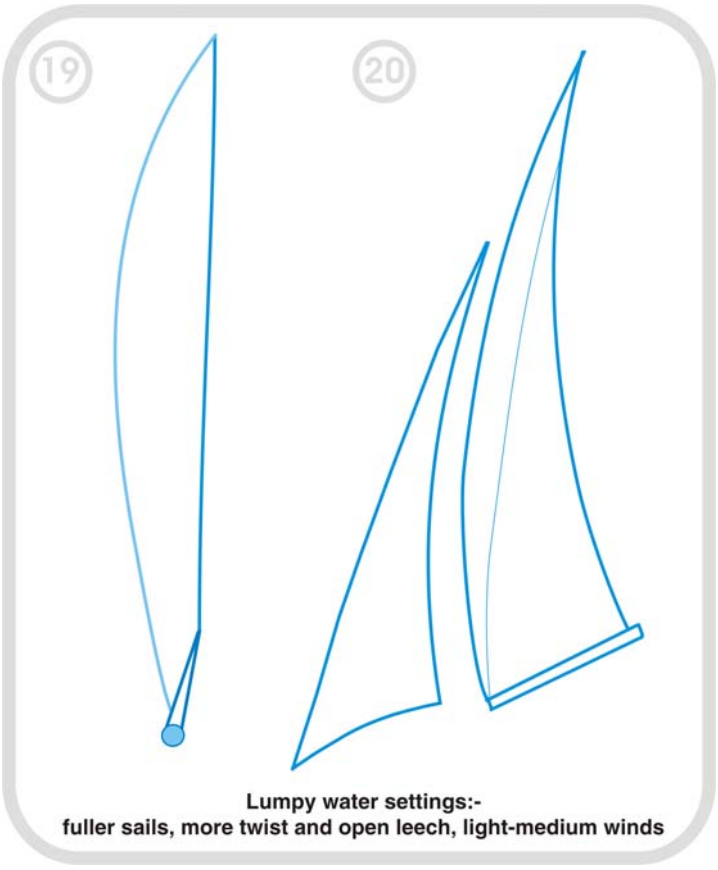
In very light airs on flat water some of the strong wind principles apply to the rig. In other words the fastest shape is a flat sail with twist. This can be achieved by pre-bending the most at deck level with, for example, a pulling system. Certain classes which do not allow "mast pullers", or those with deck stepped masts can use spreaders angled aft with the rig tensioned to induce pre-bend. Naturally, they must be easily moved forward again to reduce bend in stronger winds. The use of the kicking strap in the lightest of airs is not recommended to bend the mast, as this tightens the leech and may cause stalling. Its sole purpose should be to prevent the boom from rising. Care should be exercised with regard to luff tension as maximum fullness on the mainsail should be maintained 40-45 degrees aft. The sail should be pulled out to its black band on the boom. On boats which possess a centre main sheet system, the traveller carriage should be brought to windward approximately 9 inches and the mainsheet eased. This helps to ease the leech whilst maintaining excellent pointing ability. On boats with transom sheeting, only the lightest of mainsheet tensions should be employed.

The jib should be trimmed to obtain a weak leech and to help maintain the desired slot shape. Less tension should be used, which gives more luff sag to compensate for the lack of wind. This does not apply to pre-bent rigs as this straightens the mast.

Off wind the kicking strap and outhaul can be used from their upwind settings to achieve a fuller sail.

Sail Setting in Light – Medium Winds

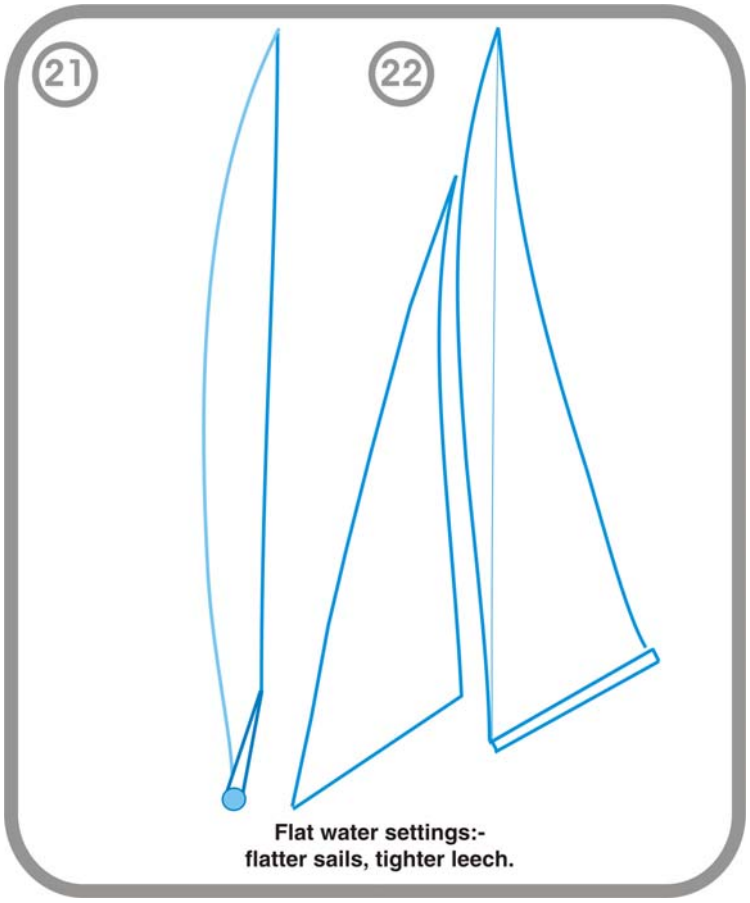
In these conditions a helmsman needs more power from the rig, graduating from the light wind settings. There do, however, tend to be discrepancies between the techniques involved in 'lumpy' and smooth water sailing. In 'lumpy' seas fuller sails and a fuller entry are required to power the boat through the chop. (fig. 19/20). A fuller entry prevents the sails stalling. The clew overhaul should be eased to increase power if needed. The most ram, if fitted, should gradually be increased to induce fullness in the sail thus developing maximum power. This forces the mast back 1/2-3/4" maximum, depending on the class of boat. The cunningham is still not being used.



Lumpy water settings:-
fuller sails, more twist and open leech, light-medium winds

In smoother water the outhaul does not need to be eased and more kicking strap tension may be used for less twist (fig. 21/22).
Slightly less mast ram need be used on flat water, a slightly flatter sail entry being faster

The rig tension can be set up tighter in smoother water giving a flatter jib and jib entry. Slightly more jib leech tension can be applied because of the flatter main entry.

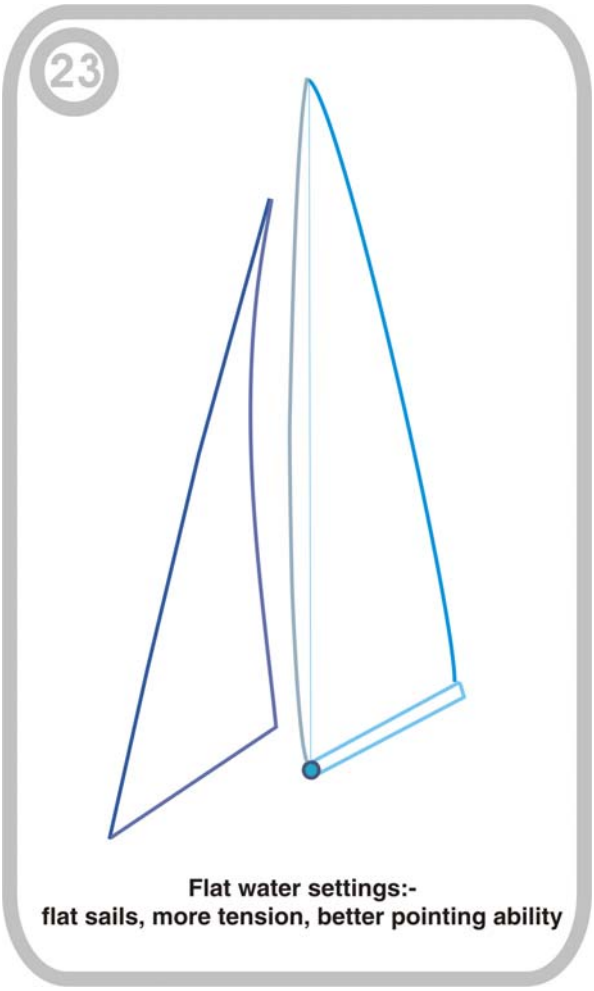


Flat water settings:-
flatter sails, tighter leech.

Sail Settings in Stronger Winds

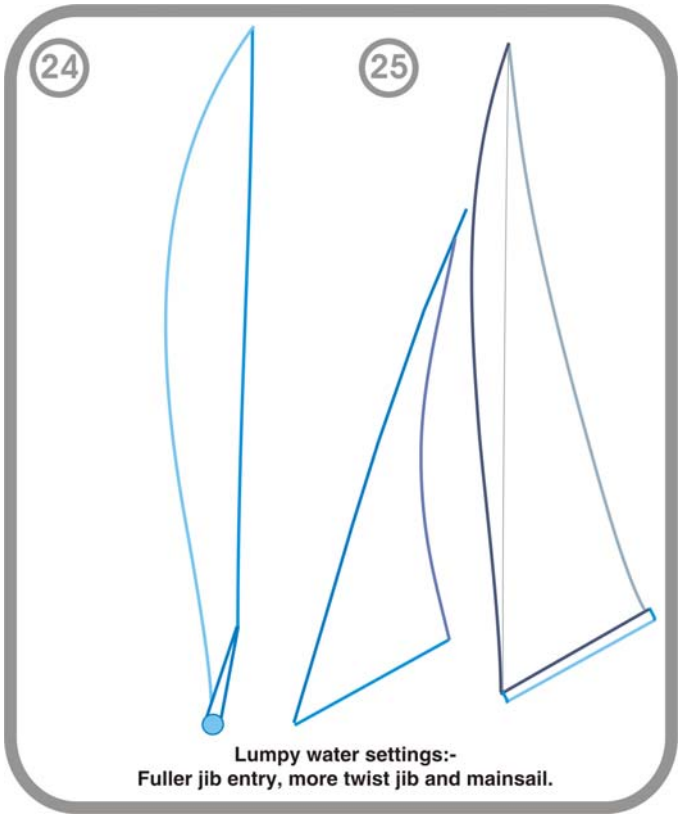
In heavy airs the rig has to be depowered gradually from a medium wind setting to suit the overall crew weight, using more mast bend to flatten the mainsail. The kicking strap can be used to bend the most throughout. The most ram, if fitted, may be gradually eased but care must be taken not to loose too much pointing ability. The boom outhaul should be tight, and the Cunningham hole used to bring the draft forward and open the leech.

In flat water the rig requires more tension in order to point and therefore more kicking strap is needed to flatten the mainsail
(fig. 23).



The jib fairleads usually need to be moved further back to ease the leech, although some classes rake the mast to achieve the same result usually where the fairleads cannot be moved.

Jib halyard tension supports the mast through the spreaders so more tension means more support and vice versa. In lumpy seas less jib halyard tension than in flat water might be used, as this allows the most to bend sideways as well as fore and aft. This provides the flexibility needed to sail in waves and helps keep the slot open. Pointing ability will suffer due to less halyard tension but dinghies, in general, cannot point so high in rough seas. The emphasis lies on footing with slightly eased sheets (fig. 24/25).



Spinnakers

On Olympic courses, reaching with the spinnaker is very important. On the standard Olympic course there are two reaches and one run. You seem to lose very little when you are dead before the wind by setting a spinnaker that is designed for reaching, because very few people sail truly dead before the wind and when the spinnaker is set it often pays to gybe downwind. In this way you have the wind on the quarter instead of dead astern which has the effect of bringing the apparent wind further ahead, which makes the spinnaker much more efficient and of course, increases the boat speed enormously.

The two adjustable controls are pole height and guy tension. Set the spinnaker pole so that both clews are horizontal, raise the pole height in stronger winds and lower it in lighter winds, then the luff should break in the middle first. The fairlead position depends very much on the class concerned. Example - Fireball, 505 and F15 should have them as far aft as possible in order to keep the slot between the spinnaker and mainsail as open as possible. The GP14 and Merlin Rocket, with smaller spinnakers and less overlap require a fairlead positioned halfway along the side deck. The spinnaker guy should be cleated level with the shroud for constant legal trimming by the crew, this also helps stop the pole from skying in strong winds. Spectra spinnaker sheets are essential for minimum stretch. Tapered sheets are an advantage, especially in lighter airs. Alternatively, a second set of smaller diameter will let the spinnaker fly better in light winds.

Tapered Spinnaker sheets link,,,http://shop.pinbax.com/index.asp?selection=category&InBox=Spinnaker%20Sheets&countstart=0

The spinnaker pole should be of maximum length allowed by your class rules and set as near horizontally as possible to obtain maximum projection and air flow between the sails. In classes where the spinnaker pole is long, such as the 505 and boats with bendy rigs, like the Fireball, it is essential to pre-bend the mast when reaching, otherwise pressure from the spinnaker pole will invert the most and make the entry of the main far to full, which in turn will close the slot between the main and spinnaker.

Spinnaker Reaching

To help increase the slot, the spinnaker should never be hoisted to the halyard exit point. Around 4" of halyard short of full hoist is usual. When the wind is forward of the beam set the pole 2" off the jib luff. If it touches it will wear a hole in the jib luff and may break your spinnaker pole.

Constant trimming of the spinnaker Is critical, easing the leeward sheet and coaxing the guy to weather until the luff is just breaking. As speed increases the spinnaker needs to be sheeted in harder due to the apparent wind moving forward. In stronger winds gradually raise the pole as this effectively flattens the head of the sail, thus reducing heeling movement. It is also essential to ease the kicking strap, When the kicking strap is completely eased and the top of the main is twisted off and still you are over powered, pull the cunningham down hard. This brings the fullness forward, bends the mast and flattens the mainsall. At this stage if you still cannot lay the mark, take the kite down, and buy a new Pinnell & Bax small spinnaker.

In lighter winds it will pay to lower the spinnaker pole to create a constant luff entry to the spinnaker.

Spinnaker Running

As when reaching, the spinnaker should never be hoisted to maximum height. It will pay to lower the pole by 3-4" from your reaching height in the same wind conditions You will find the pole height
range can vary as much as 18" from light air running to heavy air reaching.

The spinnaker pole should be trimmed to windward all the time. As a guide to how far round the pole can come, it is roughly a continuation of the line of the main boom (less in light airs).

In the lightest of airs a clean dry spinnaker will out-perform a salt-caked, and therefore damp and heavy spinnaker.